Animal-Computer Interaction: Auf den Weg zum technologisch vermittelten Multispeziesismus [Animal-Computer Interaction: towards Technologically Mediated Multispeciesity]

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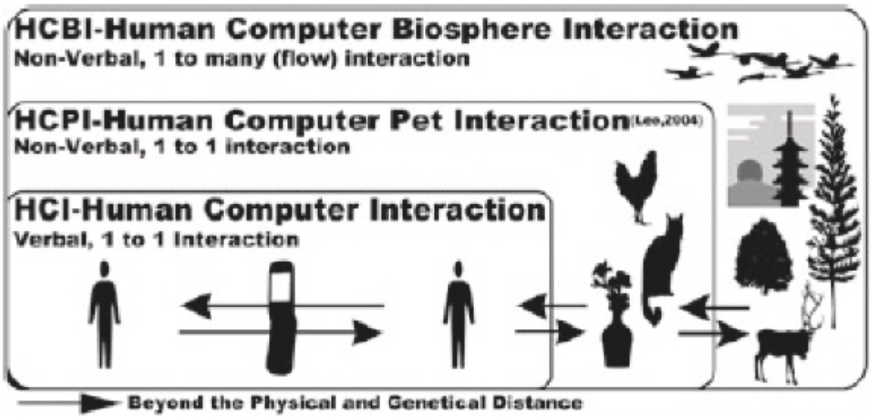
MULTISPECIES COMMUNITIES



ANIMAL-COMPUTER INTERACTION

Auf dem Weg zum technologisch vermittelten *Multispeziesismus*

VON CLARA MANCINI

Seit Anbeginn der Menschheit hat Technologie als Vermittlerin in einer Vielzahl von anthropozentrischen Beziehungen mit anderen Tieren fungiert. Diese Beziehungen haben menschlichen Interessen systematisch zum Vorteil gereicht und waren das Fundament menschlicher Zivilisationen. Angefangen von den primitivsten Jagdgerätschaften bis zu den höchst entwickelten Landmaschinen und Überwachungseinrichtungen haben Technik und Technologie Menschen in die Lage versetzt, andere Tiere zunehmend zu beherrschen, und haben unsere Wahrnehmung dieser Tiere und unsere Interaktion mit ihnen tiefgreifend beeinflusst. Dies gilt besonders für die computergestützte interaktive Technologie, die innerhalb weniger Jahrzehnte jeden Aspekt menschlicher Aktivität transformiert und sich rasch als fester Bestandteil des Alltags der Menschen etabliert hat. Computersysteme sind verwoben in das Geflecht unserer Städte, Arbeitsplätze, Häuser, Fahrzeuge und sogar unserer Körper. Sie machen es möglich, dass wir uns in bisher ungekannter Weise zu unserer Umwelt, zueinander und zu uns selbst in Beziehung setzen. Begleitend dazu hat die Einbindung von Tieren in menschliche Aktivitäten auch Tiere in wachsendem Maß dem Einfluss unserer Technik und Technologie ausgesetzt und von ihnen verlangt, mit dieser zu interagieren.

Eine auf nicht-menschliche Tiere ausgerichtete interaktive Technologie existiert tatsächlich schon seit fast einem Jahrhundert: Biotelemetrie-Geräte etwa, mit denen wild lebende Bären bei ökologischen Studien ausgerüstet werden[1], Schnittstellen für die operante Konditionierung, mittels derer Tauben in Verhaltensexperimenten trainiert wurden[2], Touchscreen-Computer, über die Menschenaffen Lexigramme zur Kommunikation mit Menschen eingeben können[3], Unterwasser-Tastaturen zur Erforschung der stimmlichen Mimikry von Delfinen[4], Roboter-Melkanlagen zur Optimierung von Milchproduktionsprozessen.[5] Bereits seit Jahrzehnten werden Hunde darauf trainiert, Bedienelemente für Menschen, wie Lichtschalter oder Bedarfs-Verkehrsampeln, so zu bedienen, dass sie für die Men-

1 Vgl. Samuel/Fuller: »Wildlife Radiotelemetry«.

2 Vgl. Skinner: Cumulative Record.

3 Vgl. Rose u.a.: »Koko's Mac II«.

4 Vgl. Reiss/McCowan: »Spontaneous Vocal Mimicry and Production by Bottle Nose Dolphins (Tursiops Truncatus)«.

5 Vgl. Rossing/Hogewerf: »State of the Art of Automatic Milking Systems«.

Animal-Computer Interaction: towards technologically mediated *multispeciesity*

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ABSTRACT: This paper introduces the field of Animal-Computer Interaction (ACI) and its fundamental aims: understanding the interaction between animals and technologies; designing animal-centred technology that improves animals' welfare, supports their activities and fosters positive intra- and inter-species relations; and developing animal-centred methods that enable animals to participate in the design process. Through examples of work conducted in different areas within the field, the paper then articulates the reasons why such aims should be pursued, particularly at this historical time, demonstrating the importance of ACI as a discipline and as a worldview for animals, humans and the ecosystems we all share. Ultimately, the author argues, it might be in our species' best interest to give animals their fair share of representation and control through animal-centred design processes and outcomes, and to invite them to co-design technologically mediated environments and futures with us, so that we could all benefit from the collective wisdom and strength of *multispeciesity*.

Introduction

Since the dawn of humanity, technology has mediated a multitude of anthropocentric relations with other animals, which have systematically benefitted human interests and on which human civilisations have been built. From the most primitive hunting implements to the most sophisticated farming machinery and monitoring devices, technology has enabled humans to exert increasing control over other animals, and has profoundly influenced our perception of and interaction with them. This is especially true of computing-enabled interactive technology, which within a few decades has transformed every aspect of human activity, rapidly becoming integral part of humans' daily life. Embedded in the fabric of cities, workplaces, homes, vehicles, clothes and even bodies, computing systems allow us to relate to our surroundings, one another and even ourselves in unprecedented ways. Concomitantly, animals' involvement with human activities has increasingly exposed them to our technology and has increasingly required them to interact with it.

In fact, interactive technology targeted to nonhuman animals has been in existence for the best part of a century: for example, biotelemetry devices fitted on free-living bears during environmental studies (Samuel and Fuller, 1994), operant interfaces used to train laboratory pigeons in behavioural experiments (Skinner, 1959), touch-screen computers allowing great apes to use lexigrams to communicate with humans (Rose et al.,1987), underwater keyboards developed to study dolphins' vocal mimicry (Reiss and McCowan, 1993), robotic milking systems introduced to optimise dairy production processes (Rossing and Hogewerf, 1997). Meanwhile, for decades, dogs have been trained to operate human interfaces, such as light switches or traffic lights, to carry out tasks on behalf of their assisted humans (Mancini et al. 2016). More recently, a host of products for companion animals have made their appearance, such as tracking collars (Swagerman et al. 2018) or tele-conferencing systems (Golbeck and Neustaedter, 2012), enabling people to monitor and remotely interact with their cats and dogs.

But how do technological interactions take into account the capabilities, activities, social dynamics, overall experience and welfare of affected animals? Do these technologies reflect animals' perspective? To what extent do animals' needs and wants inform the design of technologies they interact with directly or indirectly? How could animals shape the processes through which such technologies are developed as well as the outcomes of such processes? This kind of questions have for decades underpinned the development of disciplines such as Human-Computer Interaction (HCI) and Interaction Design (ID), which are concerned with phenomena surrounding the interaction between humans and computing technology, and with the user-centred design of interactive systems. But it is only at the turn of the millennium, researchers started to explore the possibility of applying the principles of user-centred design to the development of interactive technology for animals (Resner, 2000; Lee et al., 2006). Indeed, their increasing exposure to and interaction with technology has made it increasingly necessary to extend the paradigms of HCI and ID to include animals. Animal-Computer Interaction (ACI) addresses this necessity.

Towards Animal-Computer Interaction as a discipline

In 2011, Mancini (2011) called for a concerted effort towards the systematic development of ACI as a discipline. The author's Manifesto for the development of such a discipline proposed the following aims (quoted in full):

1) Understanding the interaction between animals and computing technology within the contexts in which animals habitually live, are active, and socialise with members of their own or other species, including humans. Contexts, activities, and relationships will differ considerably between species, and between free living, companion, working, farm, or laboratory animals. In each case, the interplay between animal, technology, and con- textual elements is of interest to the ACI researcher.

2) Informing the development of interactive technology to:

i) Improve animals' life quality or expectancy by facilitating the fulfilment of their physiological and psychological needs. Technology that encouraged healthy habits in animals or allowed them to modify their housing conditions at leisure might be consistent with this aim; similarly, technology that contributed to the refinement of animal farming or research procedures reducing their potential harm to the individuals involved might be consistent with this aim.

ii) Support animals in their activities and legal functions in which they are involved, by minimising any negative effects and maximising any positive effects of those functions on the animals' life expectancy and quality. Technology that gave farm animals control over the processes in which they are involved, produced only negligible side effects on the animals involved in conservation studies, or made it easier for working animals to perform and communicate might be consistent with this aim.

iii) Foster interspecies relationships (e.g. between humans and other animals) by enabling communication and promoting understanding between parties. Technology that allowed animals to play with their humans, or that enabled guardians, carers and researchers to understand and respond to the interests and needs of their animals, or that brought animal perspectives into the assessment and development of human–animal relations might be consistent with this aim.

3) Developing user-centred approaches to the design of technology intended for animals, informed by the best available knowledge of animals' needs and preferences, to allow them to participate in the design process. Consistent with this, ACI appropriately should regard animal *users as legitimate stakeholders and design contributors throughout all the phases of the design process and beyond.*

At the crossroads between different fields - including animal behaviour, cognition, ergonomics and welfare, anthrozoology and animal geographies, computer science, informatic, engineering and design - ACI inherits from HCI and ID a strong focus on user-centred design and on individuals' experience within technologised contexts (Mancini, 2013). Of course, the notions of animal-centred design and experience of technology are challenging in different ways. For one thing, they directly challenge the prevailingly objectifying and exploitative relations that humans have established with other animals and that have given our species certain evolutionary advantages. For another thing, such notions imply humans' ability to understand and embrace the perspective of those whom we regard as 'other' from us. In other words, pursuing the proposed ACI aims means dealing with very significant design, methodological and ethical challenges, arising from the interspecies differences, communication barriers and power asymmetries that characterise our relationships with other species. Nevertheless, there are very good reasons why such aims should be pursued, particularly at this historical time. The following sections endeavour to articulate these reasons through examples of work conducted in different areas within the field - illustrating the progress that ACI researchers are making - in order to demonstrate the importance of ACI as a discipline and as a worldview for animals, humans and the ecosystems we all share.

Reducing the impact of technology

Computing technology is increasingly used to monitor and manage animals or their living environment. The use of biotelemetry with free-living, captive or companion animals often involves fitting individuals with wearable devices that record data about their location, activities, physiology or surroundings. Although humans are the intended users of such devices, animal wearers are most directly affected by their use and the negative impact that wearing the technology can have on their welfare is well documented (Paci et al. 2019). Especially in the wild, where animals have to fend for themselves, biotelemetry may injure wearers (e.g. by rubbing against their skin or remaining caught in vegetation), impede their daily activities (e.g. by preventing them from hunting or escaping predators) and disrupt their social interactions (e.g. by interfering with courting or mating rituals), thus curtailing their chances of survival and reproduction. Albeit not to the same extent, companion animals can also be affected by the use of biotelemetry. As a case in point, a study conducted by Paci et al. (2020) investigated the responses of cats to off-the-shelf tracking collars marketed as 'cat friendly'. The authors' ethological observations evidenced behavioural alterations related to the presence of the tracker, including persistent scratching in the collar region as well as biting and cuffing of the device, indicating that the cats were negatively affected by its presence.

Aside from impacting the welfare of individual wearers, when it comes to understanding animals and their circumstances through the use of biotelemetry, the influence of the technology's presence on their behavior can compromise the quality of the data collected through its use, such that what is being recorded is the technology's interference rather than the wearers' natural behaviour. While ad-hoc design guidelines to address both welfare and data reliability issues already existed, Paci et al. (2019) argued for a more systematic approach to designing biotelemetry, for which they proposed a wearer-centred design framework. The framework enables designers to systematically consider a wide range of design variables to meet the requirements of animal wearers, based on their sensory, physical and cognitive characteristics, activities, social context, and living environment. While the framework also accounts for the requirements of human users and for any technical variables designers might have to negotiate, the authors' aim was enabling designers to identify and prioritise animal wearers' needs and to develop devices that are imperceptible, unobtrusive and cognitively acceptable for the wearer and their significant others (e.g. mates, young; prey, predators). To demonstrate its viability, the authors asked groups of designers to apply the framework when (re-)designing one of the previously tested cat trackers and later found that the newly designed version afforded significantly greater 'wearability' for the cats.

This work highlights one of many ways in which human technology impacts on other animals. Even when we are moved by the best intentions, it takes a conscious effort to recognise and respect their needs. While making such an effort is always desirable, including when designing technology targeted to companion animals, it is arguably especially important when the subjects of technological interventions are already experiencing life-threatening challenges, as is the case with species who are at risk of extinction and who are often involved in conservation studies that utilise biotelemetry. Although conservation is concerned with species, ACI draws attention to the individuals who are impacted by technological interventions, and whose wellbeing might one day make the difference between the survival and the extinction of a critically endangered species. Systematically focusing on animal stakeholders when designing technologies that affect them directly or indirectly is becoming increasingly important, if we are to preserve the natural ecosystems on which we all depend.

Fostering empathetic human-animal relations

Aside from its physical effects on animal wearers, biotelemetry can influence human-animal interactions through daily practices that the animals themselves contribute to shaping. In a multispecies ethnographic study of dog-tracking practices, Mancini et al. (2012) investigated how tracking collars might influence the interaction between dogs and humans, and how each might make sense of the technology. Their analysis of technology-mediated human-dog interactions showed how the use of GPS trackers changed the human-dog interaction dynamics by changing the behaviour of human users (e.g. they might increase or decrease their interference in their dogs' movements), which in turn changed the behaviour of the dogs (e.g. they might start gravitating around their humans or use new tactics to avoid their interference). As expected, the authors found that humans made sense of the technology at an abstract level, interpreting the symbols, icons and indexical movements on the application's interface to make inferences about their dogs' safety or pack dynamics, and decide whether and how to intervene. On the other hand, dogs established indexical associations between the physical device (i.e. the tracker collar itself) and its use in different contexts within shared human-dog practices, which allowed them to make predictions about what might happen next (e.g. going on an exciting walk off lead or being left home alone). In other words, the dogs attributed meaning and responded to the technological artefact and associated events, as they would with other objects and events in their environment, in order to optimise their engagement with their surroundings. This highlights how, even when it is targeted to human users, technology is not a neutral presence for animals; on the contrary, they engage in active sensemaking around it and respond to it based on contextually established associations.

Later studies have shown the complexity of human-animal interactions mediated by technology when actors do not have the kind of direct, one-to-one relation typically existing between humans and their companion animals. Aspling and Juhlin (2016) conducted an ethnographic study of wild boar hunting during which the hunters employed the use of mobile proximity sensor cameras and automatic feeders over a long period of time. The authors showed how the technology mediated a complex, diffuse and indirect game-like interaction involving strategies and counter-strategies between humans and wild animals in a setting that was at the same time technological and naturalistic. Other work has shown how, even during occasional and brief encounters, technology can significantly influence, in both constructive and disruptive ways, multiple, distributed and transient human-animal interactions. Through a series of situated interviews, Webber et al. (2016) studied the role of various technologies deployed in zoos - and used by visitors to learn about animals, by zoo personnel to educate visitors, and by keepers to interact with resident animals - drawing attention to the importance of the context in which multiple, multispecies socio-technological interactions occur to explain their complexity. In related work (Webber et al., 2017), the same authors designed and studied the effect of an interactive installation for orangutans. Through observations of and interviews with zoo visitors, they found that watching the orangutans' interaction with the technology elicited cognitive, affective and motor empathy for the animals, highlighting the potential that interactive technology has to influence humans' perception of animals and transform human-animal relations.

The nature of such an influence and transformation, of course, depends on the extent to which the design of technology is informed by a proper understanding of its context of use and the needs of the animals involved. In this regard, Lawson et al. (2015) point out the risks that certain technologies might pose. The authors conducted a study of pet owners' and animal behavioural experts' responses to speculative designs for pet quantification applications. They found that owners tended to desire technology that had little scientific justification, while experts were concerned that using technology to augment human-animal communication could in fact undermine the animals' welfare and the human-animal bond (e.g. by taking the human's attention away from the real animal in favour of their virtual representation), and even create human-animal conflicts (e.g. by giving humans information they previously did not have). On the other hand, when they evaluated a prototype application designed to inform pet owners about their pets' caloric inputs and outputs, and exercise and movement habits, Nelson and Shih (2016) found that providing pet owners with objective information about their animals' health through personal visual representations could benefit the human-animal bond.

For better or for worse, it seems clear that, as the role of interactive technology in humans' daily life continues to increase, human-animal interactions are going to be increasingly mediated by it. Therefore, it is crucial to ensure that the contexts for which such technologies are developed are adequately understood and that applications are designed from an animal-centred perspective with the concurrent contribution of interdisciplinary expertise. This is important not only to safeguard the wellbeing of affected animals, but also to foster empathetic and mutually beneficial human-animal relations.

Improving human-animal co-operation

The importance of designing from an animal-centred perspective is especially evident in the case of animals who are required to routinely interface with technology and whose role is to mediate humans' interaction with the environment. Having co-evolved and co-operated with humans for millennia, dogs are often given tasks, which involve interacting with a wide variety of human-centred technologies or for which technological support is altogether unavailable. For one example, mobility assistance dogs are trained to carry out a range of daily tasks on behalf of their assisted humans (e.g. switching lights, calling elevators, activating traffic lights). However, the human-centred interfaces they have to interact with on a daily basis are inconsistent with their sensory, cognitive and physical characteristics, making their job unnecessarily difficult, impinging on their welfare and on their ability to work effectively. From a dog's perspective, such interfaces contravene just about any of the interaction design principles that designers carefully abide by in order to develop user-friendly applications, posing usability and user experience challenges that for any human worker would be deemed unacceptable. Work by Mancini et al. (2016b) addressed these issues through the development of portable wired and wireless canine-centred controls consistent with dogs' sensory, cognitive and physical characteristics, which can be retrofitted in the built environment and customised to the needs of individual dogs. Evaluations by Ruge et al. (2019) confirmed that these canine-centred controls afford better usability compared to the human-centred controls the dogs normally need to use for the same tasks.

Others in the field have endeavoured to support the work of dogs in a range of occupations, from search and rescue to medical alert, by designing specialised interactive technologies. For example, Jackson et al. (2013) designed a canine vest enabling dogs to communicate remotely with their handlers during search-and-rescue or military operations. Byrne et al. (2016) further developed the vest to also enable handlers to communicate with their dogs at a distance. The vest features various canine-centred sensor-enabled input devices and vibro-tactile actuators. The technology, carefully developed by the authors to meet dogs' usability requirements, makes it possible for dogs and humans to co-operate in a way that was simply not possible before. Similarly, the vibrotactile vest developed by Majikes et al. (2016) to automatically detect dogs' postures and provide them with feedback during training sessions was designed to compensate for humans' lack of accuracy and timeliness and thus support the dogs' learning process by improving humans' communication with them.

Developing technologies to appropriately support animals in their professional tasks is also critical when the aim is to access knowledge that the animals are able to acquire thanks to skills that humans are lacking. The case of bio-detection dogs trained to recognise the odour of pathogens (e.g. cancer, viruses, bacteria) in biological samples (e.g. urine, sweat, breath) is an example. To unambiguously communicate to their handler when they find a target odour, bio-detection dogs are typically taught to use a conventional signal (e.g. sitting down in front of a positive sample). However, the use of such conventions only allows the dogs to provide binary responses (i.e. yes or no) and does not allow them to express nuances related to odour (i.e. pathogen) concentration, thus limiting the amount and quality of information they could potentially communicate. Working with bio-detection dogs and their trainers to re-centre signalling practices around the dogs, Mancini et al. (2015) designed a canine-centred sensor-enabled system that captures the nuances of dogs' spontaneous responses to target odours. Johnston-Wilder et al. (2015) later found promising correlations between sample content and patterns in the recorded data. These findings highlight the importance of animal-driven solutions for supporting human-animal co-operation effectively.

All too often, we humans expect other animals to adapt to the environments we build or the systems we develop to achieve our purposes, but in our objectifying interactions with animals we often neglect to give them the tools they need to achieve their potential and we miss the opportunity to learn from them. Designing technology that enables animals to express their capabilities and conduct their activities in their own way can enhance our co-operation with them, and can help us understand, value and learn from the capacities and knowledge they have acquired through millions of years of evolution.

Enhancing animals' welfare

Beyond supporting working animals' co-operation with humans, it is widely recognised that we have duty of care towards those animals we keep and manage. In this case too, animal-centred technology has a role to play, particularly for improving the welfare of animals who live in captivity, temporarily or permanently, where their daily experience is more often than not severely limited by a range of procedural and economic constraints. In this regard, animal-centred technology could fulfil different functions, as discussed by Mancini et al. (2014), who investigated the potential benefits of smart technology for improving shelter dogs' welfare. Welfare-related functions could include: affording animals control over aspects of their environment and providing interactive stimulation; monitoring their behavioural and physiological parameters; managing information to support their care-givers' work. An area in which procedural and economic constraints compete with - and all too often win over - animal welfare requirements, and in which animal-centred applications could benefit animals is, of course, farming. While ACI work in animal farming is still limited, some have investigated the use of information systems to monitor and improve animal welfare in this context. For example, Carpio et al. (2017) proposed a smart farming system and application framework for cows and pigs, based on concepts of openness, transparency and data sharing for all stakeholders (in contrast to proprietary systems). The system integrates sensing capabilities, cloud and fog computing, and a mobile interface to analyse, correlate and share data relevant to animal welfare (beyond production indicators typical of proprietary systems). The authors' aim was to enhance human-animal relations as well as social interactions between groups of farmed animals, and thus benefit animals, consumers, veterinarians and policy-makers. Other work includes, for example, Haladjian et al. (2017)'s monitoring system for the early detection of lameness in dairy cows, whose aim was to enable timely treatment and thus reduce unnecessary suffering and even premature death.

Various other investigations have produced interactive systems to enrich the daily experience of animals in zoos, including orangutans, parrots and elephants. For example, Gupfinger and Kaltenbrunner (2019) designed and evaluated a range of animal-centred prototype musical instruments and interfaces for rescue grey parrots, using a combination of electronic and tactile (natural and artificial) materials, in order to give the birds the opportunity to create their own music. Similarly, Pons et al. (2017) prototyped a system that allowed orangutans to control the sounds of an installation in their enclosure by manipulating physical objects available to them and thereby provide information as to their musical preferences. Additionally, French et al. (2020) designed and evaluated a range of prototype input and output devices for the acoustic enrichment of elephants, with particular consideration for the aesthetic aspects of the elephants' experience. Other work has explored the possibility of creating animal-centred intelligent playful environments. For example, Pons et al. (2017) used sensor-enabled technology and artificial intelligence to analyse cats' responses to the movements of small robots and to allow the robots to dynamically adapt their behaviour during play sessions, thus providing the cats with an individually tailored experience.

While there appears to be a growing market for digital games targeted to companion animals, Baskin and Zamansky (2015)'s work highlights the importance of gaining a better understanding - grounded in animal behaviour science - of how the interaction with human-centred technologies might affect animals. Using canine ethograms (i.e. descriptions of a species' behavioural repertoire), the authors analysed and interpret dogs' behaviour as they interact with gaming applications on tablets, finding that the dogs' responses to the game range from playful engagement to frustration and even aggression. Zamansky (2016) also analysed how dogs are affected when they come into contact with drones used by humans, stressing the need to take an animal-centred perspective when developing technologies that animals are bound to become increasingly exposed to.

Indeed, the technologised environments that we build are often inhospitable to many of the animals who occupied the land before us and even to those who live with us. At the same time, we have established segregated spaces in which billions of animals are trapped, often depriving them of what makes life worth living and giving them no control over their environment. Designing technologically supported environments that account for the diverse needs of their inhabitants, and that afford them all a measure of control, could help us redress the balance between the interests of humans and those of other animals, enabling us to create more ecologically and ethically sustainable worlds.

Broadening participation

But whatever we might design and regardless of our best efforts to proceed from an animal-centred perspective, ultimately it is only the animals we design for who can tell us whether what we produce responds to their needs and wants, and what these are. In other words, there is no *designing for* without *designing with*. Of course, the interspecies differences, communication barriers and power asymmetries existing between humans and other animals make 'designing with' particularly challenging. Many ACI researchers and practitioners have been grappling with such a challenge, endeavouring to adapt or develop research methods that enable animal stakeholders to actively participate in the design process. For example, Robinson et al. (2014) worked with medical alert dogs trained to detect the signs of upcoming critical episodes in their assisted humans (e.g. hypoglycaemia for sufferers of diabetes), to design a canine-centred alarm that would enable them to summon help remotely. In order to enable the dogs to influence critical design decisions, the authors adapted a 'quick and dirty' prototyping technique, often used in interaction design, to engage in physical conversations with the canine users. They formulated a modular template for the alarm, consisting of many interchangeable components, so they could present canine participants with different configurations in rapid succession and observe their response (e.g. their willingness to engage, the effectiveness of their interaction).

Within a playful context, Westerlaken and Gualeni (2016) used physical artefacts as catalysts for interaction between humans and dogs. The researcher's interaction with the dogs did not follow predefined goals but instead evolved freely and fluidly in time through the physically grounded actions of human and canine, together with and facilitated by the artefacts that mediated it. Somewhat similarly, French et al. (2017) took a 'research through design' approach when developing an interactive system for the acoustic enrichment of elephants. They spent several years working with elephants and their keepers and, over many iterations, explored a range of input and output devices directly informed by the elephants' responses. A more hands-off approach was demonstrated by Hirskyj-Douglas et al. (2016) to assess dogs' interest in audio-visual content as a part of their research into designing interactive media for canine entertainment. The evaluation process was almost entirely driven by canine participants, who were free to roam in a familiar room and to engage with different videos displayed on adjacent screens, while cameras recorded their head's movements as an indicator of their shifting attention. Within a different context, Ruge et al. (2018) developed a tail-wagging ethogram to assess dogs' affective responses during the evaluation of canine input devices. In their co-design work with orangutans and domain experts, Webber et al. (2020) drew from and adapted qualitative and quantitative methods from interaction design (e.g. Wizard of Oz prototyping techniques) and animal welfare science (e.g. preference and motivation tests), enabling the animals to actively contribute to the design process over an extended period of time.

Whether such methods and design practices are actually participatory from the perspective of the animals involved has been a debated topic within ACI. For or example, for Lawson et al. (2016), animals' lack of language and consequently their inability to represent their own needs, to initiate ideas and raise concerns, and to share decision-making powers, would effectively exclude them from participating in the design process. Unable to deny anthropomorphic projections or resist anthropocentric prejudice and devaluation, animals would more likely be the objects of use rather than the subjects of participation. While Hirskyj-Douglas et al. (2015) concede that participatory design with animals might be possible, the authors argue that this could only be the case if animals were allowed to engage with research set-ups and artefacts entirely on their own terms. However, much of animals' interactions with technology is somewhat constrained, in terms of the contexts in which the interaction takes place, the purposes of the interaction, and the forms that the interaction may need to take, none of which the animals involved necessarily define or choose. The question therefore arises as to whether in practice there is any scope for animals' participation within ACI research.

In this regard, Mancini and Lehtonen (2018)'s work showed how, in spite of interspecies differences and even within the constraints of structured procedures, animals are capable of expressing preferences and suggesting alternatives, through a co-constructive interaction process underpinned by each party's *semiotic*, *volitional* and *choice-full* engagement. The authors pointed out how the inevitable limitations of any design context are accounted for by the interaction design process and its iterative cycles, whose function is to unravel the layers of complexity characterizing interaction design problems. They described interaction design as a process of incremental orientation towards an optimal final outcome that may never be reached, but that can be approximated; and suggest that attending to the process by carefully crafting spaces and procedures which foster the emergence of participatory engagement is more important than any interim design outcome. The authors proposed that, in order to foster participatory engagement, multispecies participatory spaces should be crafted along four dimensions: *biological salience* (requiring that research set-ups offer each participants something of what they want); *signal reliability* (requiring that signals used within a research set-up enable participants to form meaningful associations between events); *engagement options* (requiring that research set-ups offer sufficient options to orientate the design process through successive iterations); *contingency variation* (pertaining to variations along the other three dimensions). For the authors, reframing participation could help researchers move beyond anthropomorphic participatory models, and consequent anthropocentric participatory practices, towards models and practices that are more inclusive and resilient to diversity.

Furthermore, Chisik and Mancini (2019) argued that the issue of animal participation in design is political more than practical and that dialogic exchange, which they regard as the foundation of participation, is always possible at least to some extent. Moving towards participatory models and practices that are more inclusive and resilient to diversity is therefore more a question of political will than a question of practical possibility. The reasons for resisting such a shift are understandable, since this would inevitably mean questioning the legitimacy of interests we humans take for granted and relinquishing at least some of the control we exert on other animals in order to serve our interests. However, the very animal-centred participatory models and practices that might affect our interests and that would require us to negotiate with the interests of other animals also have the potential to help us achieve forms of co-existence that are more beneficial for all.

Expanding ethical horizons

Arguably, conducting animal-centred participatory research implies a certain methodological and ethical commitment, and demands that we adopt research procedures that prioritise the participants' interests and welfare, as advocated by Väätäjä (2014). In this regard, Väätäjä and Pesonen (2013) produced a synthesis of existing regulatory frameworks based on their review of thirteen existing animal ethics sources, deriving a set of guidelines for designing, executing and reporting on interaction design studies involving animals. For Mancini (2016), though, conducting animal-centred research requires a non-speciesist approach and, in this regard, existing regulatory frameworks for the involvement of animals in research present fundamental limitations. While recognising animals' need for protection on the grounds of their inability to consent to their involvement in procedures that can harm them, existing frameworks essentially regard animals as instruments in an experimental apparatus, whereby their protection depends on criteria that don't necessarily reflect the needs and wants of the individuals involved and that ultimately prioritise other interests. Instead, the author argued that ACI requires an animal-centred ethics that can foster a culture of respect and sensitivity towards animal participants, and methodological conditions that enable them to express their needs and wants, allowing these to shape the design process and its outcomes.

Elaborating on previously proposed principles (Mancini, 2011), the author articulated an animal-centred ethics framework consistent with a user- and participant-centred perspective. The framework comprises four fundamental principles. The principle of *relevance* states that individual animals should be involved in research procedures only if these are directly relevant and beneficial to them (i.e. those who pay the cost of participating should be those who are set to gain from their participation). The principle of *impartial treatment* states that all those who take part in the research should be equally protected, not in virtue of their characteristics (e.g. species, sex, age, provenance) and any capacities attributed to those characteristics (e.g. sentience), but in virtue of their role (i.e. the fact that they partake in the process). The principle of *welfare prioritisation* states that researchers should respect the animals' biological integrity and autonomy (i.e. avoiding procedures that could physically or psychologically harm them, working in contexts that are habitual for them without disrupting their habitual activities, giving them space for expression and control over research procedures, using only forms of interaction that are respectful of and responsive to their needs and wants) and prioritise their interests over the interests of science and society. The principle of *consent* states that researchers should garner the animals' *mediated* consent (from those who have the necessary understanding, authority, knowledge and motivation to represent their best interests) and *contingent* consent (from the animals themselves, so research set-ups must enable them to assess whether the conditions exist for them to want to engage).

Mancini (2016) acknowledged that conducting ACI research within applied contexts raises fundamental ethical questions, as researchers might engage with socio-economic systems and practices (e.g. farming) whose very functioning is only possible because animal welfare is not the central value. In this respect, ACI researchers are called to carefully consider their own value systems when negotiating ethical boundaries between their research and the systems in which this might take place (e.g. farms, laboratories, zoos); between the interests of the animals involved in the research and those of anyone who might be affected by the research processes and outcomes (e.g. animals' caregivers); between different animal stakeholders within affected ecosystems (e.g. predator and prey). For the author, in order to effect change in the world, it is important that researchers engage with realities they might find uncomfortable, while always operating within the boundaries of an animal-welfare-centred ethics. ACI research might take place in contexts in which animals' autonomy and integrity are compromised (e.g., cows have not given informed consent to being farmed, dogs to assisting, horses to racing). But it is precisely within the contextual (and ethical) limitations of human-animal relationships that ACI research can provide opportunities for animals to assert their autonomy and reclaim their integrity, by giving them the opportunity to participate in, and thus inform, processes in which they have a stake. For the author, whether animals' autonomy and integrity are denied or promoted, whether animals are used or users, subjects or participants, is a choice researchers make within the context of specific research practices, throughout concrete research processes, in the way they regard and relate to the animals they work with, from the moment they set their research goals to the moment they write their final research reports.

Towards technologically mediated *multispeciesity*

Mancini et al. (2016a) point out how, for millennia, technology has propelled human evolution, reducing the species' necessity to adapt to natural elements, and instead making it possible for humans to create environments that meet their needs, to cross space-temporal boundaries, and to develop large social networks and economies. The authors argue that, by giving humans significant evolutionary advantages over other animals, technology has been increasingly setting the species apart from the rest of the natural world, thus shaping a multitude of anthropocentric human-animal relations within the most diverse contexts. In other words, while technology has enabled us to construct the realities in which both we and other animals live today, these realities have ended up reflecting almost entirely humans' perspective and interests, resulting in socio-economic systems that are ecologically and ethically unsustainable.

It is hard to deny that, while we have been busy building a world in which computing systems allow us to exploit natural resources and interact with our physical and social environment in unprecedented ways, we have been impacting upon other animals with little regard for their needs. But natural events are increasingly calling our attention to the close interdependencies that bind us to other species and some of the fundamental problems that affect our socio-economic systems. For one example, the recent Australian bushfires have poignantly highlighted the catastrophic effects that climate change caused by human activity is having on the environment, showing us what are likely to become regularly occurring natural disasters in a world in which the forces of nature have been disarrayed by human recklessness. For another example, Covid-19 has demonstrated the disastrous consequences of our inconsiderate encroachment on the natural world and our appalling treatment of animals, warning us that our animal farming and trade systems are the perfect breeding ground for new deadly pathogens and future global pandemics. Arguably, phenomena such as global warming and viral pandemics are testimony to the fact that continuing to cater for human interests at the detriment of other living beings cannot sustain human life in the long run. In this regard, understanding the interaction between animals and technology, designing technology to meet animals' needs and wants, and working with animals to develop technological solutions could help us think outside the 'human box', develop more empathetic connections with those whom we regard as 'other', and find new ways of using technology to begin to close the gap between humans and other animals that technology enabled us to create in the first place.

As animals are increasingly exposed to and affected by interactive technology, it is both our responsibility and our vested interest to include them in the processes that lead to the development of such technology. In this regard, we have little choice but to engage with animals within the contextual limitations of the compromised realities in which they and we exist, in order to gradually change these realities with their participation. To achieve this, we need to move beyond models of participation which demand the power of abstract thinking and communication only accessible to some humans, and which delegitimise, dismiss, disqualify, and ultimately exclude those who do not possess those capabilities from legitimately participating in and influencing design processes. We need to move towards models of participation that are more inclusive and more resilient to diversity, in order to facilitate the emergence of environments and futures that are incrementally co-constructed with those who live in and sustain them.

Designing *for* someone is recognising that they exist, that they have requirements that must be met. Designing *with* someone is recognising them as a worthy interlocutor whose voice must be heard. This does not just apply to design outcomes (i.e. animal centred interactive systems) and processes (animal-centred design methods). Because technology is so pervasive in human society, the values and practices that inform the design and development of technology inevitably end up influencing the values and practices that characterise all societal activity. Thus, in order to reflect animals' perspective and interests within the values and practices of society, we need to influence the way in which technology is designed and developed. Ultimately, it might be in our species' best interest to give animals their fair share of representation and control through animal-centred design processes and outcomes, and to invite them to co-design technologically mediated environments and futures with us, so that we could all benefit from the collective wisdom and strength of *multispeciesity*.

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